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(54) Process for the Production of Synthesis Gas

Synthesis gas is produced by partial oxidation and by a catalytic endothermic steam reforming process that is conducted in parallel. The amount of heat required for the steam reforming process is taken at least partially from the synthesis gas.

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Patent Claims

1. Process for producing a synthesis gas by converting a carbon containing feedstock under elevated pressure in an endothermic, catalytic steam reforming process and in a partial oxidation process, characterized in that a first feed stream is subjected to partial oxidation in the presence of water vapor and oxygen or an oxygen containing gas; and a second feed stream is subjected to steam reforming in the presence of water vapor; that the product gas produced during partial oxidation is mixed with the product gas produced during steam reforming to form synthesis gas; and that the amount of heat required for the steam reforming process is taken at least partially from the synthesis gas.
2. Process, as claimed in Claim 1, characterized in that the steam reforming process takes place in catalyst filled tubes, around which the synthesis gas flows from the outside and which are thereby heated.
3. Process, as claimed in claim 1 or 2, characterized in that the partial oxidation is conducted at outlet temperatures ranging from 900 to 1,700 °C.
4. Process, as claimed in any one of the claims 1 to 3, characterized in that the temperature of the synthesis gas, heating the tubes of the steam reformer, is below 1,400 °C.
5. Process, as claimed in any one of the claims 1 to 4, characterized in that the temperature of the product gas, issuing from the steam reformer, ranges from 850 to 1,200 °C.
6. Process, as claimed in any one of the claims 1 to 5, characterized in that the steam reforming process and the partial oxidation process are conducted at essentially the same pressure.
7. Process, as claimed in claim 6, characterized in that the pressure is over 25 bar, preferably in the range between 40 and 150 bar, especially between 60 and 100 bar.
8. Process, as claimed in any one of the claims 1 to 7, characterized in that the temperature of the product gas, issuing from the partial oxidation, is decreased by admixing a colder gas, before it is mixed with the product gas produced during steam reforming.
9. Process, as claimed in any one of the claims 1 to 8, characterized in that before being mixed with the product gas produced during steam reforming, the product gas produced during partial oxidation, flows around a part of the tubes of the steam reformer and, after mixing, flows around and heats the rest of the tubes of the steam reformer.

10. Process, as claimed in claim 9, characterized in that before mixing, the product gas produced during partial oxidation is run in cocurrent flow to the direction of flow in the tubes of the steam reformer.
11. Process, as claimed in any one of the claims 1 to 10, characterized in that after heating the tubes of the steam reformer, the synthesis gas issues from the steam reformer at a temperature between 400 and 800 °C.
12. Steam reformer for carrying out the process, according to any one of the claims 1 to 11, characterized in that the steam reformer is designed as an essentially vertical reactor comprising a feed line, which runs into an inlet area of the reactor, for a feed stream to be reformed; comprising a tube bottom, which defines the inlet area of the reactor and in which are fastened catalyst filled tubes, which lead away from the inlet area and the other end of which is provided with outlet openings, furthermore, comprising an outlet opening for reformed gas, said opening being disposed in the vicinity of the tube bottom, and comprising a feed line of product gas from a partial oxidation.
13. Steam reformer, as claimed in claim 10, characterized in that in the area holding the tubes, the reactor tank is divided into two areas by means of a separating wall adjoining the tube bottom.

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Process for the Production of Synthesis Gas

The invention relates to a process for producing a synthesis gas by converting a carbon containing feedstock under elevated pressure in an endothermic, catalytic steam reforming process and in a partial oxidation process.

The availability of a synthesis gas, containing in essence hydrogen and carbon monoxide, is a basic requirement for carrying out a whole series of important, industrial scale syntheses. For example, synthesis gases are needed in the production of ammonia or methanol, in the oxo synthesis and the Fischer-Tropsch synthesis, where in the individual case the crude synthesis gas is processed in such a manner that it exhibits the composition required for the respective synthesis. In addition, hydrogen from synthesis gases is also produced on a large scale. In this case the hydrogen content of the synthesis gas is generally increased first by converting the carbon monoxide content with water vapor, and then the converted gas is cleaned.

The composition of crude synthesis gases depends on both the type of production process and the nature of the feedstock used for said production. A conventional process for synthesis gas generation is the steam reforming process of light hydrocarbons, for example, methane, ethane, propane, liquefied petroleum gas (LPG), light gasoline fractions as far as up to naphtha or natural gas or rather associated natural gas. In this respect the respective feedstock that is used is mixed with water vapor and is converted catalytically in an endothermic process at an elevated temperature and at pressures ranging from about 15 to 30 bar. The reaction heat is provided by heating catalyst filled tubes with a hot flue gas. Such a steam reformer, which is often also called a primary reformer, frequently also follows a second reforming step, for the purpose of converting the residual feedstock, which has not been converted yet during the primary reforming process, for example, for the purpose of obtaining in the case of reforming natural gas a synthesis gas with a methane content of less than 0.5% by volume. This second step or secondary reforming is usually conducted autothermally. In this respect the synthesis gas of the first step is ignited in a combustion chamber in the presence of air or oxygen and is then passed through a catalyst bed at the established high temperature, thus completing the conversion of the feedstock.

Another useful process for producing synthesis gas is partial oxidation, where in a catalyst free combustion chamber predominantly higher boiling hydrocarbons, such as heavy oils or residue oils, or solid carbon containing feedstocks, such as coal, are reacted with oxygen or air to form a synthesis gas. Typical features of such a process are very high product gas temperatures ranging from 900 to 1,700 °C,

especially from 1,200 to 1,500 °C, a higher pressure, which is, for example, in a range between 25 and 150 bar, especially between 60 and 100 bar, and is thus above the conventional pressure that prevails during steam reforming, as well the production of a synthesis gas with a relatively high carbon monoxide content, which ranges, for example from 25 to 50 mole percent and is thus significantly higher than during steam reforming, where a carbon monoxide content ranging from about 5 to 20 mole percent is obtained.

As a rule, the synthesis - crude gases, produced during steam reforming or partial oxidation, must not only be cleaned prior to their use, but also be adjusted with respect to the hydrogen or carbon monoxide content to the requirements of the respective synthesis. Frequently, for example, in the production of methanol synthesis gas, the desired synthesis gas contains such a H<sub>2</sub>O to CO ratio that in the case of gas obtained by partial oxidation the carbon monoxide has to be reformed by conversion to hydrogen, whereas gas obtained by steam reforming exhibits excess hydrogen. Of course, the measures for adjusting the correct synthesis gas ratio could be reduced by combining the two production processes and by mixing the synthesis gases that are thus produced, yet the expense incurred in setting up two conventional gas production systems would more than compensate for the said advantage and make them financially unattractive.

The reason is, among other things, that, despite the large scale application of steam reforming (for example, the bulk of the ammonia synthesis gas is produced globally by steam reforming), steam reforming has a few drawbacks, which could not be solved to date in a satisfactory way.

In this respect an important point is the high energy requirement for steam reforming, which has to be met by burning primary energy carriers. These primary energy carriers, which are often a partial stream of the feed stream to be reformed, are converted to a hot flue gas, with which the catalyst filled reformer tubes are heated and from which additional heat is, indeed, recovered by steam generation and heating of the feed streams, but which, nevertheless, leads to a high specific energy consumption of the process and finally is vented as exhaust gas into the atmosphere, instead of being converted to synthesis gas.

The invention was based on the problem of developing an economical and operationally simple idea for producing synthesis gas.

This problem is solved in the case of a process of the class described in the introductory part in that a first feed stream is subjected to partial oxidation in the presence of water vapor and oxygen or an oxygen containing gas; and a second feed stream is subjected to the steam reforming process in the presence of water vapor; that the product gas produced during partial oxidation is mixed with the product gas produced during steam reforming to form synthesis gas; and that the amount of heat required for steam reforming is taken at least partially from the synthesis gas.

In the invention the first feed stream is introduced during partial oxidation into a combustion chamber in the presence of oxygen and optionally water vapor. In said combustion chamber the feed stream is partially burned at an elevated pressure ranging, for example, from 25 to 150 bar, especially from 60 to 100 bar, with the formation of a high temperature.

The synthesis gas, which is formed in this way and which is almost totally free of unconverted hydrocarbons, is extracted from the partial oxidation at an outlet temperature between about 900 and 1,700 °C and is used to heat the steam reformer, which is operated in parallel and in which the second hydrocarbon stream is converted with steam. The second feed stream is converted catalytically to synthesis gas in the presence of water vapor in a steam reformer. Then the product gases of the two reactions are mixed; and the result is a hot crude synthesis gas, the heat content of which is used to conduct the steam reforming process.

An important feature of the process, according to the invention, lies in the fact that during this process no flue gas accumulates that is required to heat some reforming step. Thus, not only the significant heat loss, which cannot be avoided despite the recovery of heat from the flue gas, is suppressed, but also no partial stream of the feedstock to be reformed or any other comparable feed fuel is consumed for heating purposes so that the feed stream is completely converted to synthesis gas or rather the cost of additional fuel can be reduced.

The catalyst-filled tubes of the steam reformer are heated in an expedient way by an immediate indirect heat exchange with the product gas, even though the use of an intermediate heat carrier cannot be ruled out.

During the heat exchange the hot product gas flows preferably in countercurrent flow to the direction of flow, which prevails in the tubes, over the tube outer wall and cools down during the dissipation of the heat required for steam reforming.

The thermal loadability of the tubes of the steam reformer depends essentially on the choice of material and the pressure differential between the tube interior and the tube exterior. Therefore, in conventional reformers, in which a pressure differential ranging from about 15 to 25 bar prevails between the almost pressureless flue gas and the reformer feedstock, outlet temperatures of the reformed gas of a maximum of about 850 or rather tube wall temperatures of a maximum of about 950 °C can be obtained with the use of conventional tube materials, with the result that a portion of the feedstock is not yet converted. For example, in the steam reforming process of natural gas at a pressure of 25 bar, a residual methane content, which can reach up to 10 to 20% by volume of the gas quantity, can still remain. Thus, the coupling of a secondary reformer to the outlet side for the purpose of further conversion is usually a necessary measure in such a process.

In the process of the invention, this drawback is eliminated. Since the partial oxidation process is conducted at a significantly higher pressure than a combustion process for producing hot flue gas, the pressure differential between the product gas, heating the tubes of the steam reformer, and the gas, to be converted in these tubes, can be held low and preferably even draw near to each other up to about 0 to 3 bar in order to obtain at the tube outlet end a gas pressure that equals the pressure of the product gas from the partial oxidation process. In this way a higher tube wall temperature and thus a higher reaction temperature can be set during steam reforming, a feature that in turn results in a complete reforming reaction, thus a smaller unconverted hydrocarbon content in the product gas. To the extent the pressure of the product gas produced during partial oxidation is significantly greater than the customary pressure ranging from about 15 to 25 bar that is used during steam

reforming, the pressure in the steam reformer can also be higher than typically chosen and can be adjusted to the pressure of the partial oxidation process. Of course, during steam reforming the unconverted hydrocarbon content generally increases as the pressure rises, but the rising reaction temperature can more than compensate for this effect, so that the steam reforming process also yields a product gas that is almost totally converted.

After being mixed with the product gas of steam reforming, the product gas, which issues from the partial oxidation process and which exhibits temperatures between 900 and 1,700 °C, especially between 1,200 and 1,500 °C, flows over the tubes of the steam reformer preferably at a temperature below 1,100 °C, since conventional tube materials can be stressed up to this temperature, provided they are not exposed to any compressive loads. Of course, the process, according to the invention, can also be carried out at higher temperatures. However, then it would be necessary to use special materials.

If the temperature of the heating gas for the steam reformer is also not supposed to be above 1,100 °C, then it is advantageous after all to move as close as possible to this limit, for example to choose a temperature between 1,000 and 1,100 °C. The steam reforming process can then be carried out at a temperature ranging from about 950 to 1,050 °C and thus with almost complete conversion.

The flow of the product gas mixture in countercurrent flow to the direction of flow in the tubes of the steam reformer is in general especially advantageous, because, as a result, the temperature inside the tube rises in the direction of flow and reaches its maximum value at the outlet end, a feature that is desired in light of a complete as possible conversion. In a few cases, however, other directions of gas flow are also suitable, for example cocurrent flow or a combination of cocurrent and countercurrent flow.

If the temperature of the product gas produced during partial oxidation is so high that a direct introduction of the gas mixture into the steam reformer is out of the question, a suitable temperature can be set, for example, by adding colder gases. Suitable gases for this addition are in particular those gases that have to be added anyway in a subsequent processing of the synthesis gas, for example nitrogen in the production of ammonia synthesis gas or water vapor, if a subsequent conversion is planned. Another possible method of cooling these gases to a suitable inlet temperature for the steam reformer is the use of a waste heat boiler, for example, with the recovery of superheated steam or high pressure steam.

Since the addition of colder gases to decrease the temperature prior to mixing does, indeed, represent an operationally simple measure, but in many cases must be regarded as an inadequate use of high grade energy, another embodiment of the invention that is better from an energy viewpoint enables the use of an even higher gas temperature than 1,100 °C, for example a temperature between 1,300 and 1,400 °C, and with the use of special materials an even higher temperature, directly for the steam reforming process.

In so doing, it is provided that the tubes of the steam reformer are divided into two separate, parallel areas, of which a first part is heated by the hot product gas produced during partial oxidation and

the second part is heated by the synthesis gas mixture. In the first part the product gas produced during partial oxidation flows in cocurrent flow to the direction of flow in the reformer tubes. This specific direction of gas flow avoids the formation of impermissibly high tube wall temperatures, because the hot product gas, which enters the steam reformer and is produced during the partial oxidation process, first dissipates heat to the feed stream entering into the steam reformer, thus to a relatively cold gas stream, the temperature of which can range, for example, from 400 to 800 °C. The result of the indirect heat exchange between the two gas streams is, first of all, large temperature differences. In this respect the relatively cold feed mixture for steam reforming brings about an adequate cooling of the tubes in order to avoid impermissibly high temperatures. As the heat exchange advances, the temperature differential decreases with the cooling of the product gas produced during the partial oxidation process. Thus, by suitably dimensioning the two subareas of the steam reformer impermissibly high tube temperatures can certainly be prevented from occurring at any spot. Following the heat exchange in the first subarea of the steam reformer, the product gas that accumulates there is mixed with the product gas from the partial oxidation process and is passed, for the purpose of an additional heat exchange, into the second subarea of the steam reformer, where, as a consequence of the reduced temperature at this stage, it is easy to conduct the operationally better heat exchange in countercurrent flow.

The product gas, entering into the steam reformer at a temperature ranging, for example, from 1,000 to 1,400 °C, can be cooled down to about 400 to 800 °C as it flows around the tubes, so that a large portion of the heat contained in the gas is used directly and on a high temperature level to produce more synthesis gas without the need for complicated methods for recovery and use of this energy elsewhere, for example, by a high pressure steam system with the necessary special heat exchangers, expansion turbines etc.

Another advantage of the inventive process over the conventional methods follows from the possibility of obtaining a synthesis gas that is converted to such an extent that no secondary reformer has to be employed any more. Thus, one can dispense not only with a system member of considerable size, through which the entire gas stream issuing from the steam reformer would have to pass in order to convert the residual hydrocarbon content ranging from a maximum of about 15 to 20% by volume, but there is also an advantage with respect to the synthesis gas yield, because in this process step to date a part of the desired synthesis gas components, formed during the primary reforming process - essentially hydrogen and carbon monoxide, are oxidized to less desired components, like water and carbon dioxide, and thus as a rule must be regarded as unavailable for the further use of the synthesis gas. In contrast, such a source of loss is out of the question in the process, according to the invention.

To carry out the inventive process, an especially suitable embodiment of a steam reformer is preferably one that is designed as an essentially vertical reactor comprising a feed line, which runs into an inlet area of the reactor, for a feed stream to be reformed; a tube bottom, which defines the inlet area of the reactor and in which are fastened catalyst-filled tubes, which lead away from the inlet area and the other end of which is provided with outlet openings, furthermore, comprising an outlet opening for reformed gas, said openings being disposed in the vicinity of the tube bottom, and comprising a feed line of product gas from a partial oxidation.



The major distinction between the design of this steam reformer and the conventional construction is that the reformer tubes have to be supported only on one side, thus resulting in significant advantages. Owing to the one sided mounting support of the tubes, i.e. owing to the absence of an inlet and outlet sided mounting of the reformer tubes, the usual problems with respect to the thermal expansion of the tube materials and the feed of feed material over flexible lines, so called pigtails, are no longer applicable. The inventive construction offers the additional advantage, that the product gas mixture flows in countercurrent flow over the tubes and is thus already largely cooled down upon reaching the outlet zone of the reactor. In this way the thermal stress on the tube bottom is reduced. Therefore, in such cases the interior of the reactor tank can almost always dispense with a refractory lining in the area of the tube bottom, whereas in the bottom range of high temperatures such a refractory lining is necessary.

In an advantageous embodiment of the steam reformer, which also permits a heat exchange with a very hot product gas produced during partial oxidation, the tubes of the steam reformer inside the tube jacket of the steam reformer are divided into two subareas, which are defined by a separating wall adjoining the tube bottom. In the area of the outlet ends of the tubes, these subareas can be connected together so that the gas mixture, issuing from the one subarea, can enter directly into the second subarea.

Other details of the invention are explained below with reference to a few embodiments that are depicted schematically in the figures.

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| Figure 1 depicts | a first embodiment of the invention, where the gas from the partial oxidation process is mixed with an inert gas.                 |
| Figure 2 depicts | a second embodiment of the invention, where the gas from the partial oxidation process is subjected to an indirect heat exchange. |
| Figure 3 depicts | a third embodiment of the invention, where the steam reformer is divided into two subarea; and                                    |
| Figure 4 depicts | a connection of the inventive process with an advantageous type of synthesis gas processing.                                      |

The embodiment of the invention depicted in Figure 1 shows a reactor 1 for the partial oxidation process and a reactor 2 for the steam reforming process of hydrocarbons. The partial oxidation reactor 1 consists essentially of a vertical reactor tank with a refractory lining 3, in which the top region has a burner 4, which is charged by means of a line 5 with feedstock - steam and oxygen - to be gasified. Below the burner there is the catalyst free combustion chamber 6, where the conversion to partial oxidation gas takes place. Below combustion chamber 6 there is a slag collection chamber 7, where solid combustion residues, which are separated out from the hot gas by means of quenching water, are collected and extracted via a line, which is not shown in the figure. The synthesis gas is extracted from the partial oxidation reactor via transfer line 8, provided with a

refractory lining, and mixed with cold gas, fed in over line 9, for the purpose of setting an advantageous inlet temperature in the steam reformer.

The steam reformer 2 consists essentially of a vertical tank, to which is fed from the top over line 10, a feed stream that is to be reformed. Inlet area 11 of steam reformer 2 is defined by a tube bottom 12, in which are fastened tubes 13, which are filled with a catalyst and hung in a downward direction. As a consequence of the merely unilateral attachment of the tubes, no special measures are necessary to compensate for the thermal expansion at system startup. Lower end 14 of tubes 13 is provided with outlet openings, which do, indeed, allow the reformed gas to exit, but which hold back the catalyst bed located in the tubes. Below the tubes there is a chamber 15, in which the synthesis gas, issuing from tube bundle 13, is mixed with the synthesis gas, which is generated from partial oxidation and is fed over line 8, and then, defined by the reactor jacket, which is provided with refractory lining 3, flows from top to bottom around tubes 13 of the tube bundle and, in so doing, heats said tubes.

Then the synthesis gas, which cools down in this process, issues from steam reformer 2 through line 16 below tube bottom 12. Since in passing over the tube bundle the synthesis gas already experiences a significant drop in temperature, before it reaches the area of the tube bottom 12, in many cases a refractory lining of tube bottom 12 is no longer necessary.

Steam reformer 2 can also be constructed inversely, i.e. the reformer tubes, which are configured so as to hang in the present case, can also be mounted on a tube bottom, which is disposed in the lower region, and can extend freely towards the top.

The embodiment of the invention depicted in Figure 2 differs from the above described embodiment in that the hot partial oxidation gas is cooled down to a suitable inlet temperature for steam reformer 2 by an indirect heat exchange in heat exchanger 17. Then the precooled partial oxidation gas is introduced into the lower region 15 of the steam reformer over line 18, which is also provided, if necessary, with a refractory lining. To cool the partial oxidation gas in heat exchanger 17, the heat exchange is carried out with a feed stream, which is fed in over line 19, for the steam reformer. In this way the feedstock is preheated to the requisite temperature, for example, between 400 and 800 °C. Of course, heat exchanger 17 can also be conducted with the use of other cooling mediums.

The embodiment of the invention depicted in Figure 3 is especially advantageous with respect to energy, because the hot gas, issuing from partial oxidation reactor 1, is introduced directly into steam reformer 2. In contrast to the abovedescribed process, the gas is passed into the steam reformer through inlet opening 20, which is attached flush below tube bottom 12 and flows around and heats a first part of the catalyst-filled tubes 13 in cocurrent flow to the direction of flow in these tubes. This inlet area is defined by separating wall 21, which is attached to tube bottom 12. After passing over tubes 13, the cooled partial oxidation gas mixes with the reformed gas, issuing from said tubes and is then passed through below separating wall 21 in order to then flow around remaining reformer tubes 13 in countercurrent flow to the direction of flow in these tubes and, in so doing, to heat said tubes, before the synthesis gas is extracted via line 16.

Lastly, the embodiment of the invention depicted in Figure 4 relates to a type of synthesis gas recovery with subsequent processing of the hydrogen recovery that is especially advantageous from an energy viewpoint. In this respect the synthesis gas is first produced according to one of the procedures described in Figures 1 to 3 and exits from line 16 at a temperature of, for example, 800 °C at a pressure of 60 bar. Hydrogen makes up 41.1% of the gas, which also contains 12.6% carbon monoxide, 5.9% carbon dioxide, 0.3% methane, 0.4% nitrogen and 39.4% steam (mole percent respectively). After a temperature drop to 700 °C, a state that ensues, for example, by injecting steam or with generation of medium pressure-steam of about 300 °C, this gas is expanded to 30 bar in expansion turbine 22.

In so doing, it cools down to about 590 °C. Then the gas in heat exchanger 23 is cooled down to the inlet temperature of a carbon monoxide conversion, said temperature ranging from 260 to 320 °C. The gas is converted in the conversion 24 to a gas, 53.6% of which is hydrogen and which contains in addition 0.3% carbon monoxide, 18.1% carbon dioxide, 0.3% methane, 0.4% nitrogen and 27.3% water vapor (mole percent respectively). After cooling down in heat exchanger 25 and separating out the condensed water through line 26, a pure hydrogen stream is obtained from the gas in pressure swing adsorption system 27. Said hydrogen stream accumulates in the line 28 at a temperature of 30 °C and a pressure of about 25 bar and is fed to compressor 29, where it is recompressed to the original pressure of 60 bar, before it is extracted as the product gas via line 30. In so doing, compressor 29 is driven with shaft 31 of expansion turbine 22. The energy delivered by the expansion turbine 22 is usually significantly greater than the energy required for the recompression, because all of the crude synthesis gas, extracted from the gas generation over line 16, is expanded so as to perform work, whereas only a smaller portion has to be recompressed again. Thus, for example, in the described hydrogen generation an additional output of about 5 MW is obtained, if the process is supposed to meet the hydrogen requirement for an ammonia synthesis system with an output of about 1,150 tons of ammonia per day.

It is self-evident that the synthesis gas processing, according to Figure 4, can also include other process steps, for example a CO<sub>2</sub> wash, a methanation, a partial conversion or other useful processing methods.

To avoid the formation of carbon black in the steam reformer when the synthesis gas cools down, the aim is that the synthesis gas exhibits preferably steam reformer outlet temperatures of about 800 °C, for example 780 °C for a synthesis gas under 60 bar of pressure. To guarantee this, it is necessary to pre-heat the feed stream for the steam reforming process to a temperature that is higher than the usual temperature. This additional pre-heating, for example to about 750 °C, instead of about 500 °C, can be done by any arbitrary method. For example, to this end an external pre-heating in a refractory heater can be provided. To the extent no other fuel can be or is supposed to be used for firing such a heater, a partial stream of the feed stream can be branched off for this purpose. To increase the temperature of the feed stream by about 250 °C, a small partial stream of about 1 to 2% of the feed stream suffices. At the same time process steam may or may not be also generated or superheated in the heater. Another type of feed preheating to about 750 deg. C can consist of a partial stream of the feed stream being fed to a burner, provided in the inlet hood of the steam reformer, and then burned. In so doing, the hot combustion gas is directly admixed with the feed

stream. In this case, too, only 1 to at most 2% of the feed stream is needed to raise the temperature by about 250 °C.

The process of the invention shall be explained below with reference to one embodiment. It is assumed that the natural gas stream exhibits the following composition (in mole percent):

Methane	93.25%	C <sub>5+</sub> -hydrocarbons	0.01%
Ethane	3.32%	Nitrogen	1.95%
Propane	0.87%	Argon	0.4%
Butane	0.19%	Carbon dioxide	0.01%

The hydrogen sulfide content of the natural gas was below 5 ppm. The natural gas is divided between the partial oxidation and the steam reformer at a mass flux ratio of about 2:1. Water vapor and oxygen are added to the inlet stream in the partial oxidation process. The ratio of water vapor to hydrocarbon is 2. Water vapor is added to the inlet stream in the steam reformer, until the ratio of water vapor to hydrocarbons is 3. The synthesis gas that is produced has on a dry basis the composition (in mole percent): hydrogen 68.3%, carbon monoxide 20.1%, carbon dioxide 10.2%, methane 0.5% and nitrogen 0.6%.

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